DIFFERENT AUTOMATION CONCEPTS IN CIVIL AIRCRAFT COCKPITS OF TODAY AND THEIR INFLUENCE ON AIRLINE FLIGHT OPERATIONS

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Summary

Although there are different aircraft manufacturers and hence different practical solutions, there is one bottom line in automation. In aviation automation is only complement to humans. It is not present to challenge the pilot's role and responsibility. The use of new technologies and implementation of new functionality are dictated only by: significant safety benefits, obvious operational advantages, and clear response to the pilot's needs and operational factors influencing his functioning. The paper will discuss different approaches to automation related to flight operations in aviation. The paper intends to demonstrate how different manufacturers' approaches follows quite similar ideas in different automated system designs. The paper does not intend to give any final say when choosing one concept or the other. That is the matter of different circumstances requiring more justifying space and different criteria than the pure scientific one.

1. INTRODUCTION

Act of piloting an aircraft involves an advanced animal working in an unnatural environment. Human natural sensors are either lacking or inappropriate. One could reasonably state that: "...humans have no natural flying ability. the means by which human fly is by harnessing nature via science and technology to bring the unnatural art of flying into the sphere of knowledge and sensibility with which we have the capability to deal." [4]

From the early days of aviation flying an airplane was often hard physical work. The larger and faster aircraft became, the more human strength was required to control them. In the early 1980s secondary flight control design (flaps and trimmers) began to utilize electrical signals from the control lever via computers to the hydraulic actuators of the surfaces.

The designer constantly searched for better performance, flying in all weathers and efficiently. Pilots needed extra sensors to compensate for the loss of some of their original cues. What was wanted and what was needed often got confused as it is always in the beginning. The number of sensors and systems fitted to the aircraft increased and were added in an ad hoc fashion. Some systems operated in ways conflicted in principle of operation with other systems fitted. In its early days automation of tasks grew in an uncoordinated fashion.

Generally speaking automation is "...the allocation of function to machines that would otherwise be allocated to humans".[10] Flight Deck Automation specifically consists of machines which perform functions otherwise performed by pilots. The hierarchy between the automation and the human is crucial. Automation should have a wide range of functional capabilities. Precise in the execution of its tasks just like copilot it should pay close attention to the captain's desires.[3]

New technology has always introduced challenges and potential operational difficulties. They lead to the emergence of new science dealing with human factors related to the interaction of pilots and advanced system in cockpit. [10] Human factors in engineering and ergonomics evolved to deal with problems thrown up during advances in automation.[4] Metallurgy, fiber optics, computer hardware and software have contributed to increased safety and efficiency of modern automated aircraft as well.

As shown in Figure 1. Human Engineering involves the relationship between humans, procedures, machines and environment. System and associated equipment must be designed to promote work in the environment with proper procedures, work patterns and personnel safety and health. Discomfort, distraction, or any other factor that degrades human performance or increases error is of major concern and must be minimized. [1]

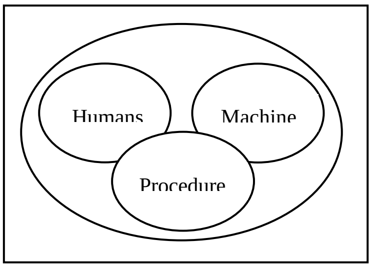

Figure 1. Human factors relationship between humans, procedures, machines and environment [1]

Automated Flight Control Systems (AFCS) limits flight envelope for pilot to use all of aircraft performance safely. [7] Boeing B777 and Airbus A320 are just some amongst today's aircraft that rely on AFCS full time.

2. PAST

Since 1910 aircraft systems have been progressively more automated (introduction of gyroscopic stabilizer, coupled navigation on the Douglas DC6, Flight Management System on the Boeing B767). [10]

Each new generation of aircraft has resulted in safer and more efficient flight. Much of original technology aviation owes to other industries. It was not that these were necessarily the most suitable technologies - they were the only means to achieve what was desired at that time.

The first aircraft performance computer was probably the analog performance computer proposed in late 1950s for the CONVAIR 990. This computer incorporated a simple flight planning option. The potential of Area Navigation to replace airway navigation was recognized as a means of operating shorter direct routes and reducing congestion in the late 1960s. One of the very few dedicated area navigation systems was Collins system specified by KLM, SAS, and Swissair for the DC10-30.

Following the oil crisis in 1973 the need to conserve fuel triggered several proposals for Performance Computer System (PCS). In the late 1970 proposals for flight management systems ((FMS) were put forward integrating Area Navigation, autopilot, PCS, and other functions. [2]

In the early days there were no dials in the cockpits. Many instruments were displaying only one information at a time(parameter) independently.

Mid 50's brought increased number of aircraft operating in more demanding traffic conditions. Since then cockpits hardly changed to early 80's. The additional info has been added in the form of new additional instruments. Conventional "dial" cockpits have usually offered the juxtaposition of many dials. With the time some limited amount of information has been integrated or synthesized.

Early 80's brought Cathode Ray Tubes. Their introduction opened two ways ahead

(a) copying the old dials or
(b) rearranging amount of data required by crew in order to properly concentrate the information provided by the aircraft systems and to take benefit of new computers. [9]

In the early 80's aeronautical world was flying through some kind of typhoon:

- there were deregulation, democratization of air travel, fast increase in the number of passenger, greater and greater cargo transport demand,
- the public expectations for flight safety became immense . The flight efficiency requirements from the operators were continuously growing,
- the technological steps forward in digital computers, display units etc. were accelerating.

This was precisely the period when Airbus Industrie decided to launch the A320 having in mind to subsequently launch the A330/ 340, in other word to give birth to and aircraft family. [13]

Airbus Industrie cockpits show the way automation has developed:

- A300B2/B4 (3 men classic cockpit, early seventies),
- A300-600 (2 men digital cockpit, early eighties),
- A320 (2 men automated cockpit, mid eighties). [5]

3. AUTOMATION DESIGN AND APPLICATION TODAY

When PCS/ FMS were firstly introduced pilots' acceptance was sometimes a problem. This could be avoided by more attention to human factors in the system design and by proper training today and in future.

Ergonomic guidelines in today's aviation regulation regarding control systems, equipment and airworthiness are very comprehensive. [5]

Each of turbine airframe manufacturers – for business aviation or airline - take great pride in its proprietary approach to automation and considers its human factors engineering to be part of its competitive positioning.

Considering automation in aircraft of today there are two main question:

- What to automate ? Pilots as workers have their strengths and weaknesses. They are best as decision makers for strategic functions while automation is better for tactical tasks: consistent accurate and safe operation, fast computations, and repetitive tasks.
- Why to automate? Automation is there to improve the safety for the sake of all; improve the comfort the sake of passenger; improve the efficiency the sake of operator and air traffic system. [5]

The fail safe design concepts hinges on the need to perform failure analysis. The best approach to this is to consider human strengths and weaknesses and thus give the pilot the role for which he is best suited. [5]

Automatic Flight Control Systems reliability required is:

$$\frac{1}{10^7} \text{ flying hours}$$

If aircraft flies 3000 hours a year that is probability of one failure in every 300 years. This probability is based on the possibility of death of healthy person within next hour. With life expectance of 75 years probability of such an event is approximately:

$$\frac{1}{1.52 * 10^6}$$

Rounded to 1/ 10e-7 means that the flight can be completed even if one of pilot dies in flight. [7]

It is act of supreme arrogance for a software engineer to imagine that he or she can imagine all the ways in which it might be necessary to fly the aircraft. Pilots should develop a confidence that they have the management skills to use automation - in real life something new will always happen.

Some present automation systems may be considered willful to the point of mutiny. To avoid that manufacturers employ pre production debugging by Computer Aided Design (CAD) programs during design. Airline personnel (e.g. airline customers, test and flight crew training pilots, airline customer pilots), interest groups (regulatory agencies , the flight training industry U. S. national aeronautics and space admin. (NASA), suppliers and research organizations) and various sources (e.g. accident/ incident reports) give inputs to manufacturers.[10]

Boeing applied that procedures in two recent major steps: developing of Boeing B777 Electronic Check List [8] and flight deck. For the Boeing 777 customers' needs were used to determine 'what' new features and functions were required and the flight deck design philosophy to determine 'how' these new features and functions would be implemented. [12]

Manufactures and users agree on the guidelines that must be followed when designing automated systems for aircraft of today. No matter whether they are called Boeing Flight Deck Philosophy [8] or Airbus Ten Design High Level Rules [5], they are very close to the user's needs.

The pilot is final authority for the operation of the airplane and is ultimately responsible for the safe operation of the aircraft. Pilot's tasks in order of priority are safety, passenger comfort, and efficiency. Automation inputs should be consistent in a given piece of equipment and automation should not produce effects which are unwanted, illogical and inconsistent with safe practice. It should always defer to humans and should never be programmed to actively counteract them.[3] The aircraft essential systems have to provide full authority to the pilot in order to achieve the maximum possible performance with a simple intuitive procedure. New products must be designed in order to make greater, not less use of the humans in the cockpit.[6]

Both crewmembers are ultimately responsible for the safe conduct of flight. The overall cockpit design should favor the inter-pilot communication. Hence first failures are dealt with automatically in order to contain the workload for two man crew to an acceptable level. [4]

The design of a new cockpit accommodates for a wide range of pilot skill levels and experience acquired on earlier aircraft and during past training. Automatic flight should follow logically from manual flight (Keep It Simple Stupid (KISS) seems a good guide).[4] The question of what is controlling the aircraft should be clear. Therefore modes and mode changes must have a consistent philosophy. The aircraft should react in a manner which is consistent with the annunciation.

The automation is considered as a complement to the pilot. Pilot's main tasks have always been: operate, navigate, and communicate (manage in today's cockpits).[9] Automation should not come in place of pilot skills. Automation must be designed to enhance the decision making abilities of the crew not replace them. It can perform many predictable tasks with a tireless precision. It lacks the ability to produce flexible response to unexpected changes in circumstances present on almost every flight.[3]

The system design process includes human factors considerations to minimize the potential of pilot errors. Switch operating philosophy should be described. It must be fault tolerant with no irreversible actions without crew attention. Transient faults should be self corrected, particularly those caused by software design deficiencies. Failure modes should be progressive e.g. alternate automatic control with gradual degradation of operation and finally either failure or restricted get-me-home type function. First failures must be annunciated. Unannounced failures that can lead to a dramatic change in capability are not at all desirable even if it upsets operators and manufacturers' dispatch reliability figures when the information is provided. [4]

The cockpit design aims at simplifying the pilot tasks by enhancing system awareness. It is true that automation lacks overall situational awareness that is critical for the safety of flight and efficiency of flight operations. Therefore, the crew should be clearly informed of the current capability of the aircraft. Pilot intervention, if required, should be minimal and at a suitable intellectual level and supported by suitable information that can be readily assimilated, i. e. graphics with values or ranges, not masses of digits. As full automation could lead to a loss of crew awareness of the primary cause of failure warning systems should be integrated with systems display. [4]

The human machine interface are optimized considering the pilot's strengths and weaknesses. The answer to many problems with present automation might be *fuzzy logic* that gives the highest priority to latest pilot’s requests. Pilot should be able to exert control without being forced to disconnect the automation except in the most extraordinary circumstances. [3] Proper annunciation of mode changes (sound) must be ensured. It is important as well that automated systems have adequate displays to keep the operator informed about what is going on, and what is programmed to happen next.

Automation design should address fundamental human strengths, limitations and individual differences-for both normal and non normal operations designing them to be selected on for all normal flight, except for manual landings. Placing more attention to making transitions pilot friendly would help to increase the probability of pilots electing to go manual sooner and more frequently. [3]

4. FUTURE

At one time fabric and string biplanes were looked upon in awe. In the course of one human lifetime, aircraft design has evolved to level far removed from those humble beginnings. The use of data systems on aircraft and in the wider air navigation system is still in infancy.

Fly By Wire Airbus aircraft have already been in airline service for more than seven years and over 700 are currently in service (operated by 10 000 pilots from over 60 operators worldwide). That fleet has logged over seven million flight hours in over four million flight cycles.[11]

We are at a point no unlike that in engineering in the year 1910. Yet the development of data processing, data links, displays, and interface devices is accelerating at a pace far exceeding that of early aviation . It is important to maintain a vision for the future, and not to be too much in awe of current applications. What is in service today is no longer state of the art. Before the first prototype of new design flies, its computer systems are already obsolete. [3]

Today's rapidly advancing technology can provide an infinite number of new products, but each has its price. An affordable product of value to the customer is of prime importance. Technology merely enables us to provide new features. [12]

Retrofitting of pilot windows with interactive data overlays (that will be more efficient to use in traffic dense airspace [6]) or evolution in display and the way pilots put together their perception of the situation in flight [9] are just some of the things coming in future.

All manufacturers and user groups agree in one fundamental fact: “Evolution of flight deck is properly controlled only if a clear cockpit philosophy is defined.“ [5]

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